THE TYPE SPECIES OF THE GENUS SERRATIA, COMMONLY KNOWN AS BACILLUS PRODIGIOSUS[1]

R. S. BREED AND MARGARET E. BREED

New York Agricultural Experiment Station, Geneva, New York

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In the recent divisions that have been made of the poorly defined and unwieldy genera, *Bacterium* Ehrenberg and *Bacillus* Cohn, some confusion has arisen regarding the selection of the type species of the red chromogenic, non-spore forming rods, and also regarding the correct scientific name to use for this species. For this reason, the authors of this paper have recently undertaken the study of a series of cultures of organisms of this group, and a review of the literature pertaining to them. The present paper presents our conclusions regarding the selection and naming of the type species for the old, but only recently recognized genus *Serratia* Bizio (1823, p. 288).

In 1918, Buchanan (1918, p. 51) reached the conclusion that the proper generic term to use for these rods was *Serratia*, and that the type species of the genus was *S. marcescens* Bizio, the organism more commonly known to bacteriologists as *Bacillus prodigiosus* (Ehrenberg) Flügge. Even earlier than this, Vuillemin (1913, p. 518) had concluded that the validity of the genus should be recognized, and had pointed out that, by right of priority, it should be used in place of one of the more commonly used terms such as *Bacillus* or *Bacterium*. He therefore proposed to select *Serratia subtilis* (*Bacillus subtilis* Cohn) as type for the revived genus *Serratia*. As this suggestion contravenes well recognized rules of nomenclature, and is appropriate only

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in case we wish to retain a very broad definition of the genus, it does not concern us further at this time.

The acceptance of Buchanan's suggestion causes the substitution of an unfamiliar name for a familiar name of a well-known and common organism so that the Committee on Classification of the Society of American Bacteriologists[2] in their final report (1920 p. 209) have suggested the use of *Erythrobacillus* Fortineau (1905) for the red chromogenic rods with *Erythrobacillus prodigiosus* (Ehrenberg) Committee as the type species. The Society also took action approving this use of *Erythrobacillus* at the Boston meeting in 1919. However, since this action was taken, various important considerations have been brought forward which change the situation. Enlows (1920, p. 41) for example, has shown that the species that must be regarded as the type for the genus *Erythrobacillus* is *E. pyosepticus*, the only species included in the genus by its author. As this species is a little known and possibly unidentifiable one, the acceptance of *Erythrobacillus* causes complications. Moreover, this suggestion, as is shown later, is not an entirely happy one as it disregards early Italian work which was of high order for the period in which it was done. For these reasons, the use of *Erythrobacillus* does not seem likely to win the general international support that all scientific names should have.

A detailed study of the early literature by the authors of the present paper has shown that Buchanan's suggestion is founded on a correct appreciation of the facts so that the recommendation was made that *Serratia* be used in the Manual prepared by Bergey (1923, p. 85).

The basis for this conclusion is found in study of the early work done by Bizio and Sette, a study carried out in the district of northern Italy where these men did their work, and in a partially completed study of a series of cultures of red chromogens

[2] The action of the Committee in adopting the name "*Erythrobacillus*" was taken in accord with the principle endorsed by the Society December 29, 1919, "That the date of publication of the third edition of Zopf's Spaltpilze (1885) be considered the beginning of bacterial nomenclature for the purpose of determining priority, with the exception of a definite list of genera conservanda."

which included one of so-called *Erythrobacillus* secured from the Pasteur Institute in Paris. The latter is probably a sub-culture of Fortineau's organism.

HISTORY OF THE EARLY WORK ON SERRATIA MARCESCENS

Although there is a long and romantic history connected with the appearance of "bleeding" bread, "blood drops" on sacred wafers, and the like that were probably caused by the organism here discussed,[3] it is not the purpose of the present paper to go back of the outbreak of so-called "bleeding" polenta (corn meal mush) that occurred among the peasantry of the little village of Legnaro near Padua, Italy, about 100 years ago. It was as a result of fine work by Bizio and Sette at this time that it was first recognized that this phenomenon was caused by a living organism (fungus) similar in many of its manifestations to the little plant (alga) causing the red snow of the alpine districts. Copies of the complete and truly scientific reports of this work have previously been inaccessible to modern students. These rare papers were fortunately found at the Biblioteca Marciana, Piazza San Marco, Venice, and phototostatic copies of them were secured through the courtesy of the Librarian, Dr. Pietro Zorzanello. The authors are also under obligation to Prof. C. P. Merlino of Hobart College, Geneva, N. Y., for aid in translating these old Italian works. He has also prepared a complete English translation of the article by Bizio (1823) which includes the description of the organism that appears to have priority. The translation will be found on the pages immediately preceding the present communication.

The story of this outbreak as told by various authors (Anonymous, (1819, 1819a), Melo (1819), Bizio (1823, 1827, 1844) and Sette (1824)) may be briefly given as follows: No little excitement was caused among the superstitious peasantry about Padua in July, 1819 by the appearance of "blood" on

[3] See Hefferan (1903) and Scheurlen (1896) for recent accounts of this history. Their accounts are largely taken from the less accessible but more complete story worked up by Ehrenberg (1849, 1849a, 1850, 1851, 1851a).

polenta stored in a cupboard belonging to one Antonio Pittarello. The disturbance became so great that the police authorities were forced to take cognizance of the matter and appointed a commission to investigate. This was largely composed of professors from the University of Padua. Others became interested and studied the matter independently. Among these was a young pharmacist, Bartolomeo Bizio, who was apparently the first to attempt a natural explanation of the phenomenon. This appeared as an anonymous publication (Anonymous, 1819a) in the Official Gazette at Venice, but is claimed by Bizio in his account published in 1823, and he repeats this claim in 1827 and 1844. Others like Dr. Vincenzo Sette, a physician and surgeon of Piove, who accompanied the official commission in their studies of the matter at Legnaro, came to a similar conclusion. On the other hand Dr. Pietro Melo, Director of the Botanical Garden at Saonara (or Savonara), claimed that the phenomenon was due to a spontaneous fermentation of the polenta which caused the corn meal to be transformed into a colored mucilage.

Melo's paper was the first to appear in print and it is this paper by Melo that Bizio had seen before his publication in 1823. In this he combats Melo's ideas vigorously. His discussion is a most interesting forerunner of the great controversy that was to take place about forty years later between Pasteur and Liebig over the nature of fermentation. Bizio shows himself an apt pupil of the great Spallanzani (Locy, 1910) whose work in combating erroneous ideas in regard to spontaneous generation laid the foundation for Pasteur's work in the same field. Bizio's work is also of great interest because it shows him using methods of cultivating chromogenic bacteria on a solid medium (corn meal mush) that antedate Schroeter's similar work by fifty years. In this paper, Bizio names the organism *Serratia marcescens*.

Sette's equally careful and scientific work was presented before the Atheneum at Treviso on the evening of April 28, 1820, but he was less fortunate in securing publication. Even the report of the Proceedings of the Society put out by the Secretary, F. Amalteo (1824) did not appear until 1824 although the date

1820 is sometimes incorrectly used because the meeting took place in that year. Sette's description of the fungus appears as a footnote on page 57 of this report. Sette's complete report (Sette, 1824) appeared as a pamphlet published in Venice and there is no way of telling whether it antedates the publication of the Proceedings by the Secretary of the Society. In either case, since both bear an 1824 date, it is clear that Bizio's description has priority.

Bizio rearranged the material in his 1823 paper with some additional comments on Sette's work in his two volume work entitled "Opuscoli Chimicofisici" published in 1827. In this, his Latin description of *Serratia marcescens* is reprinted on page 289 in exact duplication of the original in the 1823 paper. However, in his (Bizio, 1844) paper published in the Proceedings of the Academy of Science at Paris, in which he defends the priority of his work at Legnaro and points out the probable identity of the phenomenon causing bleeding polenta with that causing an outbreak of bleeding bread in a French garrison, two changes appear in the description that are evidently typographical errors. One is in the spelling of the specific name which appears as "marescens" and the other is in the substitution of the word "contortis" for "confertis." Hefferan (1903, p. 314) in copying this already incorrect copy has added another error in giving the second word as "caules" instead of "acaules."

Sette's Latin description as given below appears on page 51 of his pamphlet. This description appears in identically the same form in Amalteo's report except that the footnote references are lacking and the abbreviation *Car.* is given more completely as *Caract.*

Genus Zaogalactina (32). Car. Receptaculum nullum, substantia gelatinosa similaris, forma constanti, generatio obscura (34).

Species Zaogalactina Imetrofa. Car. Granuliformis, minima, gregaria, sessilis, intense punicea.

Observatio. Ad superficiem quorumdam alimentorum aestate anni 1819 in humilioribus Provinciea Patavinae regionibus. Copiosissime observata.

The figure (32) in the original is a misprint for (33). The figures refer to notes at the end of the paper in which the derivation of the name is given as meaning "living gelatin found on food."

A free translation of the Latin description would read:

Genus Zaogalactina. Characteristics. No receptacle. A gelatin like substance of constant form, whose method of reproduction is obscure.

Species Zaogalactina imetrofa. Characteristics. Round in form of small size, occurring in clusters. Sessile. Deep blood red.

Occurrence. Observed on the surface of certain foods in the summer of 1819, in humid regions of the Province of Patavina. Occurs abundantly.

It is well to note the spelling of this binomial, as a peculiar fate has followed Sette's name, due to its having appeared in such an inaccessible publication. Montagne (1853, p. 529), Schroeter (1872, p. 110) and Trevisan (1879a, p. 62) give it as *Zoogalactina imetropha*, while De-Toni and Trevisan (1889, p. 976) use *Zaogalactina imetropha* and *Bacillus imetrophus*. Chester's incorrect spelling (1901, p. 258) *Zoogalactina immetropha* is copied by Hefferan (1903, p. 314) while Enlows (1920, p. 98) quotes the original spelling *Zaogalactina* as if it were incorrect and incorrectly gives *Zoagalactina*. Bergey (1923, p. 87) adds still another spelling in *B. impetrophus*. There seems to be no good reason for changing the spelling from the original though other spellings may be preferred by some.

Although Bizio's and Sette's descriptions were clearly drawn up independently, they are worded very much alike and are in the form used in systematic work of this period. The descriptions apply very accurately to the clustered pink and red colonies as they first appear on corn meal mush. Later the material becomes entirely overgrown if sufficiently moist and is transformed into a gelatinous mass. The young, round and hemispherical colonies were evidently regarded by both observers as stemless fungi, similar to mushrooms.

Conclusions similar to those reached by Buchanan (1918) and ourselves regarding the justice of Bizio's claim to priority have also been reached by Spica (1900) and confirmed by him as his present views in an interview with one of the authors of this paper at Padua in 1923. Professor Spica is the present Director of the Pharmaceutical Institute of the University of Padua, and his views have double value because he is acquainted with the rare publications discussing this outbreak at Legnaro. The historic institute of which he is the director may well have been the institution at which the young pharmacist Bizio received his training. It is situated on the Via Fallopio, a name that reminds us of the splendid scientific history of this famous university. It seems especially fitting that the credit for the discovery of the natural cause for the so-called miraculous appearance of "blood drops" on various foods should also go to men from this university, as the superstitions connected with this natural phenomenon have been responsible for many executions and murders of innocent persons in Italy as elsewhere in Europe.

Although these discoveries were reported a century ago, it is evident that superstitious and ignorant peasantry may still be excited by the growth of Bizio's organism on food. A colleague on the Experiment Station Staff who has lived many years in Italy states that the newspapers of Naples reported the disturbances that were excited in that city as recently as 1910 or 1911 when a "bleeding host" was found in one of the churches. This caused many ignorant people to seek the protection of the priests as did the similar outbreak in northern Italy.

Following the work done by Bizio and Sette, the next most important work was that by Ehrenberg. His interest in the matter began in 1848 when his attention was called to red spots on cooked potato in a home where there had been a fatal case of cholera. At first quite ignorant of the earlier Italian work, he later obtained a copy of Sette's pamphlet but remained throughout ignorant of Bizio's work and of his discussion of the outbreak in France four years earlier. With good reason he regarded the phenomenon that he had observed as identical with that seen by Sette. While Ehrenberg's observations and experiments

with the organism are not as complete as those of Bizio or Sette, he studied the history of similar outbreaks much more completely and also had the advantage of studying the material under the improved microscopic lenses of the period. From the microscopic examination, he discovered that the red material was made up of incredible numbers of tiny, isolated, oval animalcules which, because of their motility he regarded as animals. He even goes so far as to imagine that he saw a single polar flagellum in one of his dried preparations. This was perhaps half as long as the body. Reproduction is stated to be by longitudinal fission. Because of these conceptions, the majority of which are now known to be erroneous, Ehrenberg proposed to substitute a new name for the organism in place of the name given by Sette. Ehrenberg's description (1849a, p. 359) is as follows:

Monas prodigiosa (= *Mucor sanguineus* de-Col = *Zaogalactina imetrofa* Sette) corpusculis $\frac{1}{8000}$ – $\frac{1}{8000}$ lineae longis, subrotundis, singulis hyalinis, acervatatis sanguineis, proboscide corpore breviore. In cibis humidis interdum copiosae sanguineas maculas gelatinosas efficiunt.

In pollice cubico uno 46,656,000,000,000 ad 848,736,000,000,000 vivunt. Habitat in Syria et Europa.

A free translation of this would read:

Monas prodigiosa. Corpuscles from $\frac{1}{8000}$ to $\frac{1}{8000}$ lines in length, ovoid, when single, hyaline, when massed together, blood red, bearing a flagellum shorter than the body. Occasionally found on moist food as abundant blood red gelatinous spots. The number living in a cubic inch varies from 46,656,000,000,000 to 884,736,000,000,000. Habitat Syria and Europe.

It is interesting to note that $\frac{1}{8000}$ of a line is a little less than 0.5 μ while the larger dimension would be about 0.75 μ figures that are commonly given as the size of these bacteria. The number per cu. in. is undoubtedly based on computations made with a microscope. The habitat given is due to Ehrenberg's knowledge of the numerous occurrences of this organism in various parts of Europe and in the bread of Alexander the Great's troops in their siege of Tyre.

Ehrenberg's assignment of this organism to the animal kingdom was soon challenged by Montagne (1853). The latter's interest in the matter arose through the appearance of the organism in its characteristic way on some cooked chicken that had been stored over night in a cupboard in a warm kitchen. This happened on July 14, 1852, while the author was visiting a friend in the country near Rouen, France. Montagne, who had just read Ehrenberg's work and who was also familiar with Sette's work reported on the matter to the agricultural society of Paris soon afterward. In his report, he disputes Ehrenberg's claim that the organism is an animal, and assigns it to the algae under the genus *Palmella*. Specimens were displayed showing the organism growing on cooked rice and on chicken. The author stated that even under a magnification of 1200 diameters he was unable to find the flagellum mentioned by Ehrenberg and that he regarded such movement as he found as being caused by an exaggerated Brownian movement caused by the very small size of the organism. In the discussion of the paper, it was pointed out that various reproductive cells of the algae were known to be able to swim by means of flagella so that even though flagella were present, Ehrenberg was not for this reason alone justified in calling the organism an animal.

DISCUSSION OF NOMENCLATURE AS APPLIED TO SERRATIA MARCESCENS

Among the generic terms that have been applied to this organism, the following are properly applied to species of algae rather than of bacteria: *Protococcus* as used by Meneghini (1848), *Palmella* as used by Montagne (1853) and *Micraloa* as used by Zanardini (1863). Among other terms suggested there are several that are today applied to genera of bacteria, but in each case the present tendency is either to drop the term or to so limit the genus as to exclude Bizio's organism. This statement applies to *Bacteridium* of Schroeter (1872), *Micrococcus* as used by Çohn (1872), *Bacillus* as used by Flügge (1886) and *Bacterium* as used by Lehmann and Neumann (1896). *Coccobacterium* as used by

Schmidt and Weis (1901), *Liquidobacterium* as used by Orla-Jensen (1909) and *Erythrobacillus* as used by Fortineau (1904) and Winslow et al. (1920), like *Zaogalactina* of Sette are invalid synonyms of *Serratia* Bizio. *Monas* as used by Ehrenberg is now used only for a genus of Protozoa so that it is no longer available.

Among these names *Serratia* has clear priority and should be accepted unless general usage indicates that a return to this early name would be unacceptable to a great majority of bacteriologists. However, a glance at the list of synonyms on a following page will show at once that there is not and never has been any general international usage regarding the generic term applied to this species. From this standpoint there appears to be no good reason for disregarding the law of priority.

The situation in regard to the specific name *marcescens* is not so fortunate, as Ehrenberg's specific name *prodigiosa* has been much more generally used, though various Italian workers have followed either Bizio or Sette. In order to retain Ehrenberg's specific term some one of the genera suggested since his time must be chosen. When this is attempted it will be found that this causes complications in every case as has already been shown for *Erythrobacillus*. Because of these difficulties and because the specific name *prodigiosa* perpetuates the erroneous conclusions drawn by Ehrenberg in place of the splendid pioneer work done by Bizio, it seems far better to accept *Serratia marcescens*, retaining the term of miracle (prodigium) bacterium for use as a trivial or common name.

Synonymy

The preliminary study of the series of cultures has already shown that this somewhat variable organism has been renamed several times since 1848 by workers who thought they had something new. Proper determination of this fact is always difficult and can only be made after the study of the cultures is completed so that a complete list of synonyms cannot be prepared at this time. It is, however, evident that all of the following combinations are exact synonyms of *Serratia marcescens* Bizio (1823, p. 288).

Synonyms—*Zaogalactina imetrofa* Sette (1824, p. 51); *Protococcus imetrophus* Meneghini[4] (1838); *Monas prodigiosa* Ehrenberg (1849, p. 359); *Palmella prodigiosa* Montagne (1853, p. 527); *Micraloa prodigiosa* Zanardini[4] (1863); *Bacteridium prodigiosum* Schroeter (1872, p. 110); *Micrococcus prodigiosus* Cohn, (1872, p. 153); *Micrococcus metrophus* Trlevisan, (1879, p. 19); *Bacillus prodigiosus* Flügge (1886, p. 284); *Bacilus imetrophus* Trevisan (1887, p. 799); *Bacillus marcescens* De-Toni and Trevisan, (1889, p. 976); *Bacterium prodigiosum* Lehmann and Neumann (1896, p. 259); *Liquidobacterium prodigiosum* Orla-Jensen (1909, p. 338); *Erythrobacillus prodigiosus* Winslow et al. (1920, p. 209).[5]

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[4] Original not found, Quoted from Trevisan (1887, p. 799).

[5] The term *Mucor sanguineus* De Col also sometimes appears in lists of synonyms. This term is ascribed by Sette (1824, p. 19) to De Col, a chemist from the University of Padua, who studied the outbreak at Legnaro and who became interested in the possible commercial value of the pigment extracted from these organisms. However, De Col does not appear to have ever published this name. At least no trace of the publication could be found either in the library at Venice or at the University of Padua. As it does not appear to have been effectively published, it is a hyponym, not a synonym.

Coccobacterium is given by Schmidt and Weis (1901, p. 9;1902, p. 10) as a generic term and they list *Bacillus prodigiosus* as the typical organism of this genus. However, the binomial *Bacillus prodigiosus* is used throughout the book.

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